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Report No. 105-1

INTERIM REPORT
OF MAINTENANCE STUDY
PHASE I, DEFINITION

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1.0 Summary

This report reviews the maintenance problem, presents observations made during the definition phase, and suggests a set of tasks to be accomplished during the final phase to generate a complete maintenance program.

The problem in its entirety extends somewhat beyond purely maintenance considerations in the usual sense of the term. In addition to establishing a capability for prevention, detection, and repair of malfunctions, there is need to formalize quality considerations during the procurement process. The training and experience of the maintenance organization could be employed profitably in influencing equipment design and in acceptance evaluations.

The recommended plan for organization and implementation of the maintenance program involves 28 weeks of contractor effort. It is expected that this work would be accomplished within 9 months. The program would be implemented in stages building in strength and responsibility gradually from the present level over the next 6 - 9 months.

2.0 Introduction

The information contained in this report is the result of a three month contract providing for 30 days of consulting services to perform a detailed analysis of maintenance requirements. The study was the outgrowth of several in-house efforts which called attention to the growing problem of equipment maintenance and promoted interest in a planned approach to establishing an in-house maintenance capability.

The Plans Branch of the Plans and Developm ent Staff initiated action on the maintenance problem with Staff Study, TCS 1001-63-KH which was presented to the Executive Director 10 January 1963. This study suggested establishment of an in-house maintenance capability under the Assistant for Administration. When no action was forthcoming a second study in January 1964 recommended a Maintenance Branch be formed under the direction of the Assistant for Plans and Development. Action in this regard was subsequently initiated and a Maintenance Section established under the Development Branch, Plans and Development Staff.

The current study is based on the above work and on a draft memo by the Chief, Maintenance Section which outlines manpower and material requirements, major functional responsibilities, and plans for operation of the Maintenance Section.

Contractor assistance was obtained to aid in the development of the maintenance management program. To facilitate contracting, this effort was divided into two parts, one concerned with defining requirements and the other with development of procedures required for implementing the maintenance program.

Phase I, Definition of Procedures, had as its objective specifying maintenance requirements in detail, identifying the steps necessary to implement a maintenance program appropriate to these requirements, and establishing the effort necessary to complete Phase II of the study. In the course of defining the problem certain specific tasks were also accomplished which contribute directly to planning and organizing the maintenance capability.

3.0 The Maintenance Problem

The objectives of a maintenance program are to assure both that the equipment is operating when needed and in accordance with desired standards of quality. The effort to provide such benefits quite obviously requires the expenditure of funds. These factors of quality, availability, and cost have, in fact, been major considerations in proceeding to establish an in-house maintenance capability. The maintenance effort to date, however, has been mostly concerned with keeping equipment operational rather than with the quality aspect. In large part this has been a matter of necessity. Greater complexity in equipment design inevitably results in more frequent failures and, hence, greater repair effort. To achieve the desired level of equipment availability (readiness) it was expedient to acquire the services of qualified technicians on a contract basis.

Under certain conditions and for certain types of equipment the use of maintenance contracts is a wise choice. If the equipment plays no critical role in the operation or if the frequency of service needed is out of proportion with the level of training required contracts may be the best approach. For the bulk of equipment, however, contract service personnel, either resident or on-call, is not economically sound. Obviously, cost is not the only factor to be considered, competency to perform the required tasks is essential. One objective of this study then, is to specify the level of in-house capability required to maintain equipment at the level of quality for which it was designed at the least cost.

3.1 Cost Considerations

Staff studies have already indicated the possible benefits of an in-house maintenance capability on purely economic grounds. For fiscal year 1965 active maintenance contracts with private firms and Government agencies exceed $100,000.00 annually. This figure does not include amounts for services on an "as needed" basis, a method used for some of the more complex instruments.

These contract costs, of course, include amounts for indirect expenses of the supplying organization and, in some cases, profit and travel. Obviously, then, similar level personnel employed directly by the agency would provide the same amount of time at less cost. There is, however, a practical consideration in that these contracts include a variety of equipment, each of which requires some particular knowledge and training. However, substantial savings could be achieved by elimination of only the two largest contracts which account for over 80% of the total. The chief obstacle to such a move now is manpower rather than level of capability.

The concern with maintenance contracts is not, however, primarily one of reducing costs, as admirable as this might seem to the economy minded. Obtaining full value for whatever is spent is the real issue. There is no ideal amount or rule of thumb to specify what maintenance costs should be. Rather it is prudent to spend whatever is necessary to achieve the desired level of quality. Determining what that level of quality should be and how to maintain it is the major concern.

3.2 Quality Considerations

The goal of a complete maintenance program is not merely to provide a repair capability but to strive for a high level of quality and reliability. To this end the major concern of maintenance is preparedness and prevention. The former activities are aimed at discovering malfunctions which are not necessarily apparent in normal operation. Preparedness activities include such functions as inspection, test, operational check-out, alignment, and calibration. Such activities are essential to preserving accuracy in readings and measurements. In the absence of regular frequent tests, the reliability of information generated is subject to serious doubt.

Prevention, on the other hand, is concerned with minimizing the probability of failure of parts subject to fairly predictable deterioration. The failures or malfunctions connected with such parts are usually quite obvious and are generally of the "catastrophic" variety in that a failure results in complete stoppage of the equipment. Preventive tasks consist of cleaning, lubrication, adjustment and similar measures intended to prolong the life of a particular part. Although preventive maintenance is most frequently associated with mechanical devices, similar attention is now also being given electronic equipment as well. Periodic replacement of parts or components with known life characteristics can prevent costly operational failures.

The least significant aspect of a maintenance program, although still essential, is the repair and replacement of failed and damaged parts. While this effort is necessary to efficient operation it does not offer the contribution to assuring quality

that is inherent in the preparedness and preventive procedures.

Maintenance is all too often considered only as "fixing" something after it has failed or been damaged. The major problem confronting your organization is not merely developing a capability for such efforts but the organization and management of an in-house service to assure the highest possible level of equipment performance. What is urgently needed is the capability to maintain your valuable instruments at the level of their design specifications. If it is necessary that instruments be procured to very high standards of precision it is equally important that they be maintained to those same standards. Such an effort is far more than a repair activity.

The quality problem stems from the gradual and imperceptable deterioration of equipment. It results in a lower quality of work and increased performance time. Degradation of viewing and measuring equipment results in increased eye strain, fatigue, and errors. The daily wear and tear on instruments, the bumps, the interchange of critical parts, the accumulation of dust and dirt all contribute to misalighment, light loss, and inability to focus properly. Because the effects are gradual and because there are no standard routine tests frequently applied, instruments remain in use which are well below their original design specifications.

4.0 Study Results

Phase I of the study has consisted of gathering the background information necessary to a complete understanding of the maintenance problem. The effort has been devoted to obtaining and reviewing records and equipment literature, observing operations, and discussing maintenance problems and viewpoints with various personnel. This effort, in addition to forming the framework for future work, has also contributed directly to the organization of the in-house maintenance effort.

As a prelude to specifying the maintenance organization, personnel, training requirements, and schedules it was necessary to determine just what maintenance functions were essential to the objectives of availability and quality. To this end the analysis was concerned with the type and quantities of equipment in use, the operating procedures and environment affecting the equipment, and the maintenance measures currently employed. The problem was somewhat complicated by the absence of an accurate equipment inventory, differences in nomenclature, and uncertainties as to whether specific items were in use or not. Although uncertainties remain about the precise numbers of some equipments, the information is adequate for current purposes. Specifically, the following tasks were accomplished:

1. equipments requiring regular routine maintenance were identified,
2. the nature of the maintenance tasks determined,
3. appropriate preparedness and preventive procedures prepared, and
4. methods for establishing maintenance schedules investigated.

4.1 Equipment Requiring Regular Maintenance

If the problem were simply one of keeping equipment operating this subject would require little attention. However, as previsouly discussed, to reduce unexpected failures, extend the useful life, and to assure quality it was necessary to determine which equipments required routine attention. The instruments vary widely in characteristics, quantities, and frequency of usage. Each of these aspects had to be considered in choosing a preliminary list of items for which regular maintenance attention should be scheduled. Although most of the items of major interest have been identified some additions to the list are almost inevitable. This list is available to anyone interested although not included in this report.

4.2 Maintenance Tasks

Whether scheduled maintenance, in the form of preparedness or preventive procedures, is necessary depends on the characteristics of the equipment and its use. Equipment inventories were reviewed, the operational employment observed and the available literature studied to seek clues to the possible modes of failure of each type of item. Instruments subject to deterioration or which would benefit from preventive maintenance were examined and the particular subsystems or components of interest identified for further analysis.

4.3 Maintenance Procedures

Once the critical aspects of each instrument were identified, preparation of procedures to detect difficiencies or failures and to prevent undue wear was begun. This may prove to be a more

formidable task than originally perceived. Manufacturers operating and reference manuals proved particularly weak in the test and check-out aspect. They tend to emphasize trouble-shooting procedures for locating malfunctions once clear symptoms are perceived. The more important and far more subtle subject of how to ascertain if the instrument is functioning properly is largely ignored. It is in this area of malfunction detection that the maintenance study will be the greatest benefit. Although a start in this direction has been made the task is by no means complete. Specific tasks to be performed on much of the optical equipment will not be known until notes on the training course shceduled for 22 March 1965 are received. In other cases such as that of some of the more complex measuring instruments check-out routines will have to be developed, possibly with assistance from the manufacturer.

4.4 Maintenance Schedules

Upon knowing what needs to be done to each piece of equipment, the next question is how often to do it? Obviously, it should only be as often as necessary but establishing what is necessary is not a simple problem. A number of mathematical techniques have been developed which provide quite precise means for evaluating alternative maintenance policies or for optimizing the interval between services. Unfortunately these require data which would necessitate a rather substantial effort to develop. These techniques require failure rate data and usually costs of operation, costs of the particular maintenance, and costs of a failure during operation or not having detected one which has occured. The effort required for this approach does not seem justified at this time.

Rather than attempting to compute optimum schedules at this stage it is more practical to adopt less elegant methods. In many cases the manufacturer recommends preventive maintenance intervals based on his experience with the equipment. Such information may also be extended to similar items for which no recommendations were provided. Even in the case of one-of-a-kind instrument the system usually consists of common subsystems or components for which the desired information is available.

The assignment of test or calibration intervals presents a different problem. The frequency with which such action should be performed depends on many factors beyond the control or even knowledge of those responsible. It depends on the stability of the device, operating practices, environment, degree of usage, to name a few. Rather than attempt to take these complex variables into account, a self correcting method is proposed. The intervals between preparedness action will initially be established on the basis of judgement. Adjustment of the interval will, in the case of quantity items, be made so that at each regularly scheduled service 95% of the instruments are within tolerance. In other words, if more than 5% are out of tolerance at the end of the interval, the time to the next service is shortened. A similar technique may be applied to one-of-a-kind instruments also. By increasing or decreasing the interval between service inspection a proper balance between assurance of quality and cost of maintenance can be achieved.

An additional factor in establishing maintenance intervals is the spasmodic nature of the operational activities. The wide fluctuations in work level make rigid schedules rather

impractical. If scheduled maintenance coincides with a heavy production schedule, maintenance would have to be postponed or performed during non-working hours. An alternative to this approach would be to acquire a number of "standby" instruments which would provide spares not only for scheduled maintenance but also for the inevitable failures and breakage which might otherwise delay production. Such "insurance stocks" of spare equipment might prove an economical solution.

4.5 General Observatons

4.5.1 Environment

The operational practices and the building environment are also factors contributing to the maintenance problem. The general lack of discipline in the operating areas and the absence of any assignment of responsibility for specific instruments tends to generate an atmosphere of indifference to the working condition of the tools of the trade. Despite an apparently effective air conditioning system the work areas are not maintained at desirable level of cleanliness. This condition is not enhanced by an infrequent janitorial service which is inclined more toward the rearrangement of dirt than its removal.

Now there can be little doubt that precision is proportional to cleanliness, the dirtier the environment the less accurate the measurements. Any efforts to improve the cleanliness of the operating areas or increase responsibility for instrument care will result in improved quality and reduced maintenance effort.

4.5.2 Procurement

Emphasis in procuring equipment, whether of a developmental nature or off-the-shelf, tends strongly to the technological aspects. Whereas this is the objective of an organization charged with the responsibility for innovation, these efforts should not lose sight of the requirements for efficient operation after acceptance of the item. If an instrument is to be effectively utilized consideration of reliability, maintainability, spares, and documentation should be consciously considered early in the development process. Similarly acceptance requirements need be specified so that technical evaluation may be conducted against standards clearly understood by producer and buyer. To the extent possible evaluation should be on a quantitative basis.

4.5.3 Scope of the Maintenance Effort

As is indicated previously in this report the problem as presently viewed extends somewhat beyond purely maintenance considerations as commonly construed. The maintenance function is normally constrained to the prevention, detection, and repair of malfunctions. The capability visualized herein encompasses these tasks and more. The concept of influencing procurement requirements and involvement in acceptance evaluation exceeds the limits of responsibility normally associated with maintenance. This need for a quality assurance function extending to the equipment acquisition process could be quite adequately and efficiently fulfilled by the capabilities to be represented in the maintenance organization. However, use of the term maintenance to describe all of these activities would be unduly restrictive, if not, misleading.

It certainly is not sufficiently comprehensive to indicate the variety and scope of activities which need attention, nor does it reflect the professional level qualifications of the group. It is, therefore, desirable to consider use of a name other than Maintenance Section to identify this function. Instrument Services Section is one suggestion.

5.0 Phase II Program

On the basis of the analysis of Phase I, it is apparent that a well planned and organized maintenance program would make a substantial contribution to quality improvement. Equipment is currently being used regularly while in substandard condition. The affects on quality of output and the strain imposed on personnel can only be detrimental. A series of tasks are, therefore, proposed the successful accomplishment of which will place the organization in a position to vastly improve the situation.

The tasks remaining to be performed fall into three distinct categories; maintenance organization, maintenance management, and inventory management. Establishing a useful and effective service is not merely hiring personnel and turning them loose. Organization and management are as essential as specifying the tasks to be performed. It cannot be expected that technicians, despite their technical qualifications, have either the experience or inclination to develop the methods and procedures necessary for management control. A major portion of the remaining study is, therefore, to be devoted to just such activities.

5.1 Maintenance Organization

The principal organizational tasks remaining are aimed at bringing the Maintenance Section to a level to assure full responsibility as quickly as possible. The following tasks are necessary to achieve this goal. The time necessary to complete each task is given opposite the title.

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5.1.1 Estimate Performance Times 2 weeks

Before personnel requirements can be established it is necessary to know the time required to accomplish both scheduled and unscheduled tasks. In some cases applicable data can be extracted from existing records. In others the tasks will have to be performed for the first time and times observed.

5.1.2 Maintenance Schedules 4 weeks

Routine maintenance for each piece of equipment of each type must be scheduled according to methods described earlier in Section 4.4. A necessary adjunct is an effective reminder and record keeping system.

5.1.3 Personnel Requirements 1 week

At this stage it will be possible to specify personnel requirements with regard to types of skills, level of experience, and quantity with considerable certainty and prepare appropriate position descriptions

5.1.4 Training Requirements 1 week

Although only highly qualified personnel are expected to be selected, some training will be required in almost every case. The qualificatons will tend to be in general fields such as electronics or mechanics. It is quite unlikely that experience with the specific equipments in your possession will be encountered. Training assignments among staff will have to be identified and planned.

5.1.5 Implementation Plan 2 weeks

Upon completion of all preceeding steps it will be possible to develop an implementation plan for acquisition and training of personnel, assumption of, responsibility, and phasing out maintenance contracts. Failure to achieve this smoothly and satisfactorily is likely to impair the all-important relations with the operating personnel and destroy confidence in the in-house capability.

5.2 Maintenance Management

Included in this general category, which might more aptly be identified as quality assurance, are a number of activities which are now performed only quite informally, if at all. The establishment of these management procedures and functions will contribute both to improved quality and usefulness of the newly acquired equipment.

5.2.1 Procurement Specifications 4 weeks

Current procurement practices for both R & D and off-the-shelf items are largely technologically oriented. There is no formalized concern with reliability, maintenance, spare parts and parts lists, manuals, drawings, and performance measures. The utility of many instruments would be enhanced by specifications and guidelines for establishing such requirements. The goal of this part of the study would be to develop such material. A procedure is also needed for the distribution and control of the manufacturers documentation.

5.2.2 Acceptance Procedures 4 weeks

Receiving inspection and technical evaluation of incoming equipment requires formalizing. If specifications are established

as in 5.2.1 above, new instruments can be evaluated in quantitative terms. If the sample to date is indicative, the Maintenance Section is already frequently involved in acceptance and evaluation. Particularly with the more complex instruments the technical knowledge represented there is often called upon simply to render the item operational upon arrival. Much greater dividends would result from evaluation procedures designed to exercise each new item to its fullest capacity and with a minimum of personal bias. Objective test procedures are required.

5.2.3 Operational Evaluation 3 weeks

The introduction of new equipment to operating personnel, or attempts to, can be a traumatic experience. The natural reluctance to change presents real barriers to acceptance. Furthermore, if measures for evaluation of instruments are not provided, each individual will supply his own. These may be such irrelevancies as the color of the knobs, the slope of the control panel, or the length of the power cord. Operational evaluations require planning and missionary work. The personnel performing the evaluation tests must be acquainted with the purpose of the instrument and objectives of the test. Proper conditioning and communication can make the test personnel partners in the evaluation. But a most important task is developing the criteria on which acceptance should be based. The more this can be placed on a quantitative basis the less one must depend on subjective judgements.

5.2.4 Trouble and Failure Reporting 1 week

Records of repair and preventive maintenance action are currently

being kept. With possibly slight modification the form now in use should suffice. A means for utilizing this information remains to be devised. The data being generated must be reduced and analyzed and the results distributed to appropriate action points.

5.3 Inventory Management

Along with the in-house capability for maintenance it is necessary to establish a central store for spare parts and the means to efficiently manage the stock. Although the Maintenance Section has begun to stock spares little effort has as yet been devoted to organizing the system. The steps described below would establish a more formal yet simple inventory control system.

5.3.1 Spares Provisioning — 2 weeks

It is not now known just what spares are on hand. They have been ordered by different people and are stocked in different locations. A spares inventory and a central storage point are both needed as a starting point.

The problem of spares for new equipment is related to the management aspects discussed in 5.2.1 above. Rules-of-thumb are required to determine initial spare requirements and procedures are needed to provide for them at the same time equipment is received. Expeditions around town to purchase small parts are costly and time consuming.

5.3.2 Reordering — 2 weeks

Simple economic reorder rules are needed to minimize outages of standard stocks.

5.3.3 Inventory Control 2 weeks

Procedures are needed to combine all aspects of the inventory problem and to distribute information to the points of action. Simple stock records are required and centralized parts ordering authority established.